UDC 621.397.63
621.377

1969
THE QUEEN'S AWARD
TO INDUSTRY

RESEARCH DEPARTMENT REPORT

Field-store standards conversion: the field-store synchroniser

No. 1971/38

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

FIELD-STORE STANDARDS CONVERSION: THE FIELD-STORE SYNCHRONISER

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UDC 621.397.63
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It uses SI units in accordance with B.S. document PD 5686.

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(EL-55)

October 1971

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Summary

The need for synchronising television signals from various sources is discussed and an outline description is given of the adaptation of the BBC CO6/508 field-store standards converter to operate alternatively as a television source synchroniser. Certain special features of the principle of operation are discussed in greater detail.

1. Introduction

One of the ways in which the presentation of television programmes has improved as technology has developed is that, as far as possible, the contributions from the multiplicity of picture sources are arranged to be synchronous. The purpose of this is primarily to provide an uninterrupted train of synchronising pulses to receivers so that viewers are not disturbed by frame 'roll-overs' or other momentary synchronising defects when changes are made between different sources. This is particularly important when the programme is being recorded on video tape; the subsequent replay from a video tape machine can be seriously disturbed for several seconds following any discontinuity in the recorded synchronising pulse train. A second advantage of having sources which are synchronous is that special effects are possible such as for example the so-called "split-screen" and overlay techniques (in which a single picture consists of simultaneous contributions from several sources) and also the ability to mix, fade and wipe, rather than cut between different sources

When the contributions are all originated within a single building there are no great difficulties in achieving synchronism since all sources can be fed from a common pulse generator and, by adjusting the timings of the pulse feeds to individual sources, precise and virtually permanent synchronism of the video signals is effected. This technique is not possible however when some programme sources are external.

A method which is currently used to cope with the problem of remote sources is the BBC Natlock[1] system in which error signals are continuously sent to the pulse generators of remote sources so as to steer them into synchronism with the local sources. This has disadvantages, however, in that circuits must be provided over which to send the error signals and an appreciable time (up to several minutes) may be required to achieve full colour synchronism. Moreover, the system cannot easily be used when for example, the distant source is mobile or in a foreign country. In an earlier method of synchronisation, known as 'Genlock' and still widely used, equipment is used to lock the local system to the signal incoming from a remote source; of course, this can be done for only one remote source at a time and can lead to operational difficulties.

The development of the synchroniser, described in this report, arose from an alternative approach[2] to the problem in which delay is inserted in the path of the incoming video signal. The value of this delay is automatically controlled so as to maintain the emerging signal in complete synchronism with those generated locally.

This method has the advantage that a signal from any remote source can be synchronised without the need either to feed information back to control its generation or to disturb the local sources to which it is required to synchronise. In addition, the time taken to bring a remote source into synchronism is relatively short – equal only to the duration of several television fields. There is however a disadvantage that, since the timing of the video signal itself has to be modified directly (rather than through its synchronising pulses as in other systems), the picture quality is likely to be degraded by the delaying process.

In a synchroniser, it is necessary for the variable delay to have a maximum duration of at least one television field period (for reasons to be given later) and this means of synchronising is therefore expensive and was not given serious consideration until the advent of the field-store standards converter.[3,4] This comprises, in essence, a controlled delay system of up to two fields duration and it is possible to use this to fulfil the alternative function of synchroniser at relatively small additional cost. This report describes the development and modification of the second BBC field-store converter, type C06/508, to function also as a synchroniser operating at the 625-line, 50 fields-per-second standard.

2. Broad description of the synchroniser operation

As stated previously, the synchroniser consists in essence of a variable delay whose duration is steadily increased or decreased, the rate of change of delay depending on the frequency difference between the local and remote sources. In the increasing state, when the delay reaches a duration of one field it is switched back to zero; thus the stored field is omitted and the cycle repeats. Conversely, in the decreasing state, when the delay reaches zero it is switched up to the duration of one field, thus duplicating the stored field. On these occasions, because

of the disturbance of the odd/even field sequence, the output picture exhibits a vertical shift or 'hop' of one picture line spacing. It was originally intended to avoid this disturbance by using the available delay capacity of two field-periods, thus omitting or duplicating a complete picture when the delay limits are reached (and hence preserving the correct odd/even field sequence). However, in practice it was found that the vertical shift was virtually indiscernible on moving pictures and the proposal was abandoned in the interests of simplicity and to avoid the significant degradation of quality produced by the inclusion of an additional delay of one field-period.

At the extremes of the synchroniser input frequency range, nominally $\pm 5{\cdot}5$ parts in 10^4, the vertical shift effect, resulting from one-field operation, occurs at intervals of about once every 36 seconds. This may be considered to be a little too often, even for a disturbance which is difficult to see, but it is also rare for the frequency of signals to be so far from the nominal. The maximum rate of change of delay when synchronising PAL colour signals (for example, an input PAL signal at the German frequency-tolerance limit) and an output signal at the opposite end of the UK frequency-tolerance limit, i.e. a difference in colour subcarrier frequencies of 6 Hz, is only 27 ns per field; in this case a vertical shift in the output picture would occur once every four hours, i.e. probably not at all in the majority of programmes.

3. Brief description of the practical synchroniser

Fig. 1 is a block diagram of the basic synchroniser and from this it can be seen that the variable delay is divided into two main stages.

3.1 Main Store

The first stage (the Main Store) consists of a system of ultrasonic fused-quartz delay lines which is controlled at field-frequency rate and provides a range of delay from zero up to a duration of one field period, the smallest delay increment being equal to about one-quarter of the duration of a television line. (A more detailed description of the form of this delay system is given in another report.)[5] The video signal is transmitted through the Main Store delay by means of a frequency-modulated radio-frequency carrier[6] centred on about 30 MHz, f.m. transmission being used to minimise the effects of the inevitable gain variations which occur as the delay units are switched in and out of circuit. The delay is controlled by logic circuits which, in effect, measure the time interval between local station field sync pulses and those of the input video signal. This action results in a re-timing of the input signal such that at the beginning of each field it is set, with an accuracy of about 17µs, to the middle of the range of the second stage of the variable delay.

3.2 Timing corrector

The second stage[7] consists of a chain of four variable delays of successively increasing accuracy. These are called Timing Correctors* and their purpose is to re-time the signal from the Main Store so that, for colour operation, it is synchronised to within a target accuracy of 2ns to the local station reference pulses and colour subcarrier.

3.2.1 Monochrome operation

The first part of the timing corrector, called 'Timing Corrector 1', operates at line-frequency rate on the r.f. signal from the main store. It comprises a chain of switched, binary-related delays with a range extending from zero to about one-half of a television line duration, the

* The terms 'Main Store' and 'Timing Corrector' originate from the alternative standards-conversion function of the equipment. In this condition the basic conversion process takes place in the Main Store which produces an output having the correct mean line frequency of the new standard but with television lines which are irregularly timed. Precise timing of the lines is achieved in the variable delay following the main store, hence the term 'Timing Corrector'.

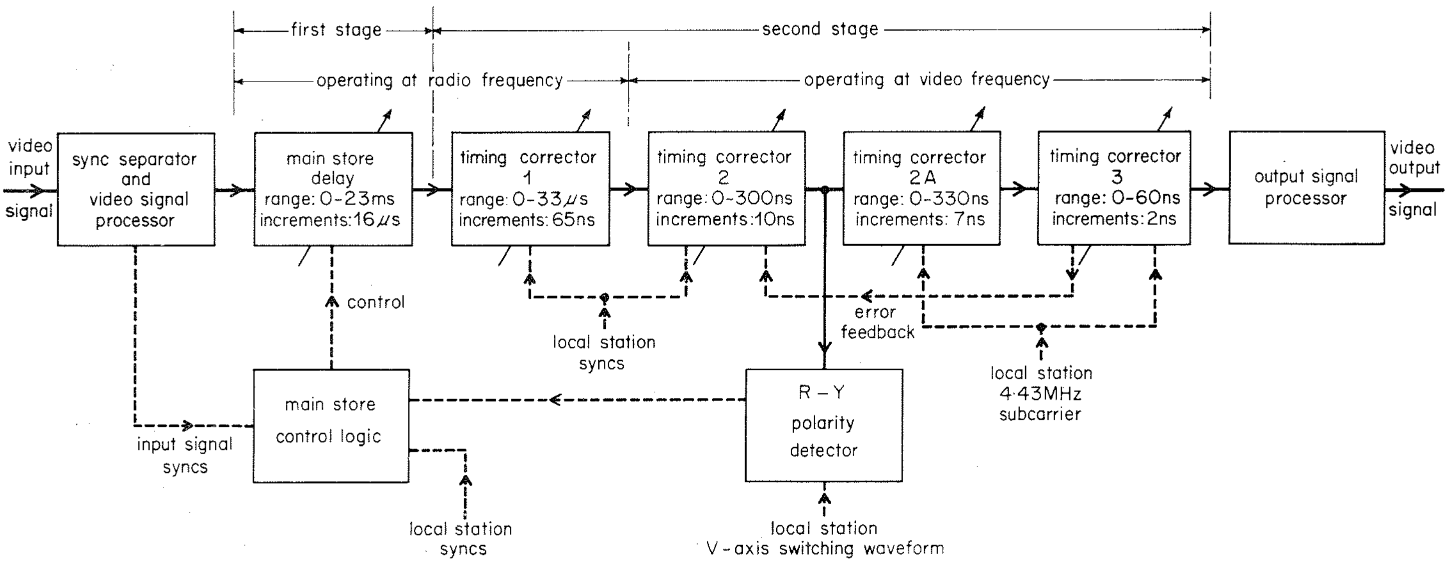

Fig. 1 - Synchroniser basic block diagram

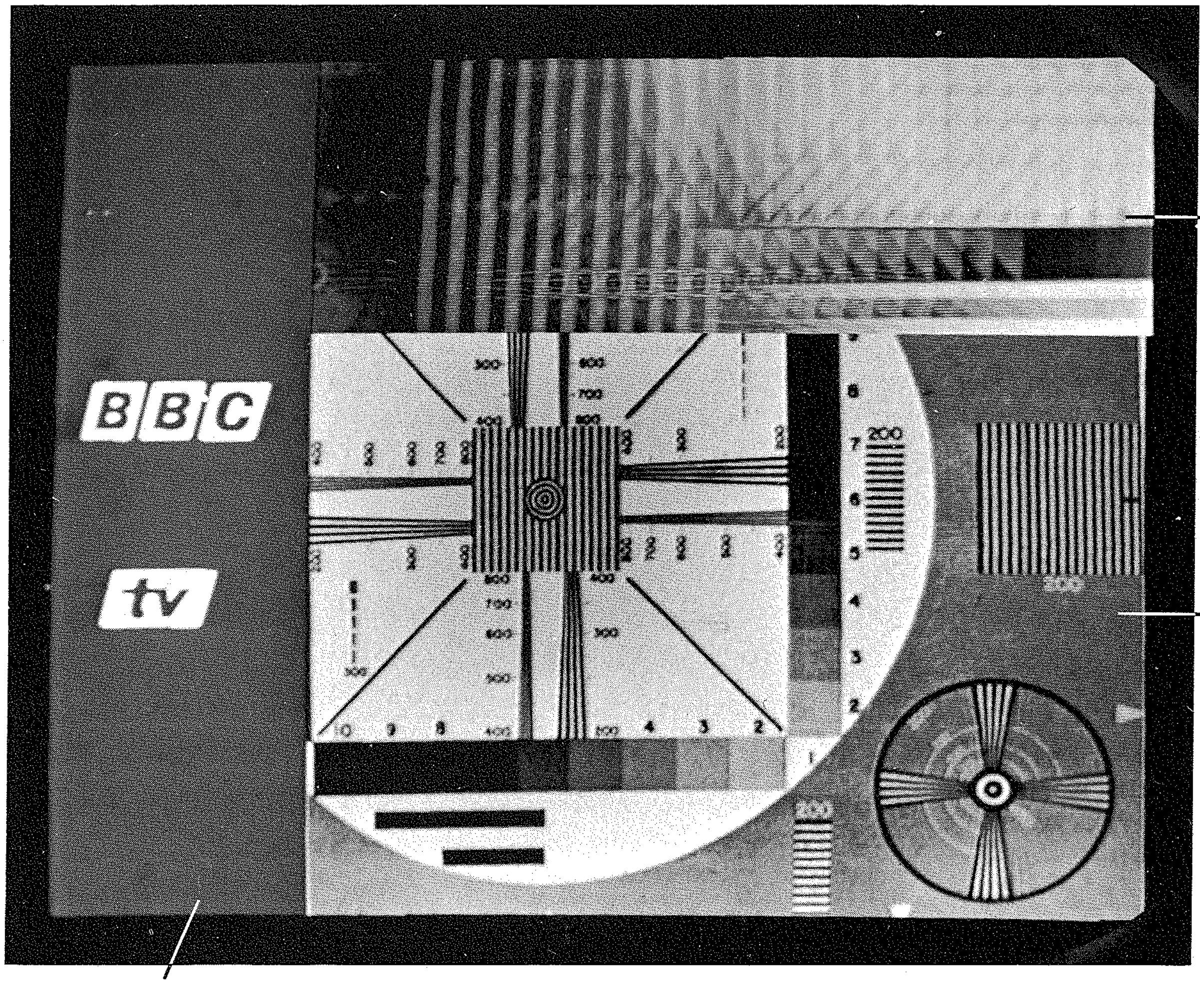

Fig. 2 - Display showing monochrome operation of synchroniser

smallest delay increment being 65ns. The next section of the corrector, Timing Corrector 2, also operates at line-rate and consists of a lumped-constant delay line of length 300ns and tapped at 10ns intervals. It operates on the video signal obtained by demodulating the output from Timing Corrector 1, and produces a signal with timing errors sufficiently small (of the order of 20ns) to be acceptable for monochrome pictures.

The monochrome input television scanning frequency tolerance of the synchroniser is determined by the delay range (33 μs) of Timing Corrector 1. At the start of each field, the signal emerging from the Main Store is timed to an accuracy of about 17 μs, thus leaving a range of 16 μs for correction (at line-frequency rate) during the field. Theoretically, therefore, the maximum possible rate of change is 16 μsecs in 20 ms (the duration of one field) which corresponds to an input/output signal frequency difference of 8 parts in 10^4. It was thought however, that to achieve this frequency tolerance in practice, the control logic involved would appreciably increase the synchroniser lock-up time, (i.e. the time between applying an input signal and obtaining a synchronised output signal, an important feature discussed in section 4.3). To avoid this, the Main Store control logic design is such that a compromise between frequency range and lock-up time is obtained; the resulting input signal frequency tolerance is about $\pm$ 5·5 parts in 10^4.

Fig. 2 is a photograph illustrating the operation of the synchroniser on a monochrome input signal having an appreciable frequency difference from the synchroniser output. By means of special split-screen techniques the composite picture was produced showing:

a) a caption on the left-hand side generated by a local source
b) the synchroniser input signal at the top
c) the synchroniser output signal at the bottom.

As can be seen, the output signal is locked to the caption reference signal whilst the input signal is not. It may be deduced from the photograph that the exposure time was equal to about $^1/_5$ second (11 television fields) during which time the input signal moved across the display a distance equivalent to about 14 μsecs. This corresponds to a difference frequency between input and output signals of about 0·6 parts in 10^4.

3.2.2 Colour operation

For colour operation, the 20ns timing errors on the output signal from Timing Corrector 2 are too great and further correction is necessary. This is done in two stages, the first, Timing Corrector 2A*, operating at field-frequency rate, and the second, Timing Corrector 3*, operating at line-frequency rate. Each of these correctors derives its control signal by comparing the phase of the input signal burst with that of a reference signal derived from the local station colour subcarrier. Timing Corrector 3, consisting of a 60ns video delay line with controlled taps at 2ns intervals, provides the essential timing correction to the required colour accuracy. The 60ns range of this corrector is however insufficient to deal with two problems which arise when synchronising a PAL colour signal.

First, there is no specified relationship in the PAL system between the phase of the colour burst and the timing reference provided by the line-synchronising pulses. Thus if, for example, one particular line in the PAL 8-field cycle from one source is compared with the corresponding line from a second independent source (i.e. one not operating from the same pulse generation system) by aligning the line sync pulses, the phases of the two colour bursts could, in general, be different by any amount up to 360°. Since the previous timing correction processes have related to the line sync pulses (for monochrome purposes) it therefore follows that the colour timing corrector must have a full 360° subcarrier phase range in order to be able to cope with any PAL source.

The second difficulty occurs when the Main Store of the synchroniser has to re-cycle, thereby omitting or duplicating a television field. This process can involve a 180° change in subcarrier phase of the signal emerging from Timing Corrector 2 which the colour Timing Corrector must also be able to accept.

It was therefore necessary to interpose Timing Corrector 2A between Timing Correctors 2 and 3. This consists of a chain of binary-related video delays with a range corresponding to 529° of subcarrier phase in 11° steps. A basic range of one cycle of colour subcarrier is theoretically adequate but, in practice, to prevent a 'hunting' effect (resulting in a small sideways movement of the displayed synchronised output picture) when operating near the 0° or 360° delay condition, an additional range of 180° was provided.

3.3 Video processing

In order to reduce degradation of the quality of the synchronised signal, video processing is kept to the minimum possible. Modulation and demodulation is of course unavoidable because of the quartz delays in the Main Store. For transmission through the equipment a special luminance timing pedestal is inserted on the line-blanking back porch period together with a special superimposed colour burst. The latter is double the amplitude of the normal burst, has a larger deviation and an exact ± 45° phase swing with accurately matched amplitudes for each phase condition. The purpose of the special burst is to obtain timing correction as free as possible from errors due to noise and burst-parameter defects which may be present on the incoming signal. It also avoids difficulties which could arise due to the absence of a colour burst on certain active lines of the incoming PAL signal which is a feature of "Bruch" burst-blanking.

Because of changes in the response characteristics of the different signal paths in the variable-delay system it is necessary to correct the resulting variations in amplitude of the chrominance component of the synchronised video signal. The low-frequency and high-frequency components of the video signal are therefore separated to permit fast, (i.e. line-by-line) automatic correction of the chrominance amplitude. Finally the l.f. and h.f. components are re-combined and standard line-blanking parameters re-inserted on the output waveform.

4. Special aspects

Section 3 of this report outlined the practical synchroniser, this section will deal in greater detail with certain special aspects.

4.1 The problems of synchronising with a delay limited to about one field

The PAL-coded colour signal is such that eight fields are involved in the cycle between identical television lines. This arises because of the odd/even field sequence, the 'V'-axis (PAL) switching at half line-frequency rate, and the relationship between the colour subcarrier and scanning frequencies; the sequence is depicted in Fig. 3. A synchroniser would ideally therefore have a delay capacity of up to eight fields in order to match precisely any incoming PAL-signal field to that of the local source. Clearly, however, this would involve an extravagant use of delay lines and would seriously degrade a signal when operating near its maximum delay of eight fields. Picture/sound mistiming would also be a problem.

In order to achieve synchronism of any PAL source with a delay capacity limited to about one field it was necessary to accept that, in certain conditions, some of the input video information would not be present at the output. For example if the remote source timing is such that odd fields are required to be displaced to become even fields in step with the local source (or vice-versa), then half of one television line of video information will be absent from either the top or bottom of the output picture.

A further difficulty arises in connection with the polarity of V-axis switching. As Fig. 3 shows there is a 50% chance that, having aligned the nearest incoming field to the output reference field, the polarity of PAL switching may be out of step. Various methods of correcting this were examined. Full PAL-to-PAL transcoding would have

* The designations 2A and 3 (rather than 3 and 4), arise because Timing Correctors 2 and 3 had already been developed for the standards conversion function and it later became necessary to interpose an additional corrector (2A) specifically to deal with the synchroniser aspect

been a solution at the cost of an additional loss of vertical chrominance resolution and other inevitable degradations of the signal quality. Alternatively it was thought that separation of the 'V' component for correction and re-insertion might be possible, thus avoiding full PAL-to-PAL transcoding, but this presented problems.

The method adopted was simply to change the synchroniser delay by one television line, as necessary, to bring the PAL switching sequence into step. This action occurs automatically in the 'lock-up' process as each new source is switched to the synchroniser, and is initiated by the 'R-Y polarity detector' shown in Fig. 1. Should field omission or duplication occur however (a very rare event with PAL tolerances) the one-line delay switching action is controlled by the Main Store logic to avoid the relatively slow sensing time of the polarity detection system.

The penalty for this simple method of overcoming the problem is that a further loss of one line of video information can occur, but this was considered a worthwhile exchange for the picture-quality degradation which would be introduced by alternative solutions. Up to 1½ lines of input video information may therefore be absent on the synchroniser output.

The final problem, the phase of the colour subcarrier, is minor, since the timing of the output video signal is merely adjusted to achieve phase synchronism with the local source. This may mean disturbing the timing by up to about one half cycle of colour subcarrier (113 ns) but this is acceptably small.

4.2 The problem of main store 'dither'

When the input signal frequency is such that there is only a small rate-of-change of delay in the Main Store, there is a small but finite risk that, should the input and output field synchronising pulses drift into near coincidence, there could be a succession of field omission/duplication actions. This is undesirable because of the consequent vertical shift or 'hopping' effects which would occur as explained previously in Section 2.

It was originally decided that precautions against the possibility of this 'dither' effect occurring in the Main Store should be taken. Accordingly the prototype controlling logic was designed so that when conditions were such that the delay was increasing, it was permitted to rise to a value of about $1^{1}/6$ fields duration before re-cycling. When, however, the delay was reducing, re-cycling occurred when zero delay was reached (negative delay is of course impossible).

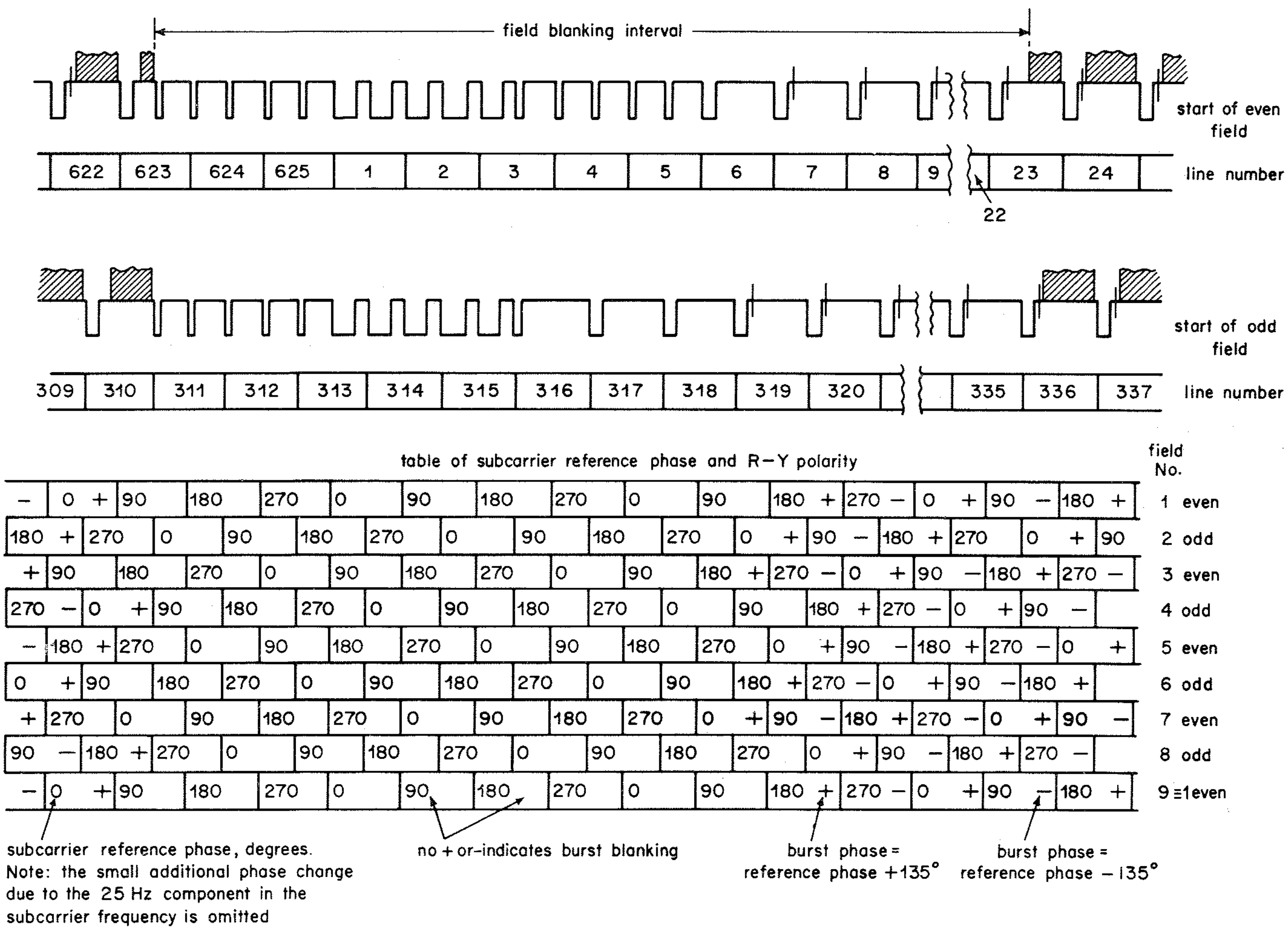

Fig. 3 - Diagram illustrating the PAL 8-field cycle

The incorporation of this 'backlash' in the Main Store operation involved considerable complexity in the controlling logic and faultless operation was never quite achieved. With hindsight, the alternative solution against 'dither' of introducing a separate 'backlash' delay preceding the synchroniser would have been much simpler to implement. In the event it was decided to discard "anti-dither" measures when the final logic was engineered in the interests of simplicity, reliability and on the basis that the probability of "dither" occurring is extremely small.

4.3 Synchroniser 'lock-up' time and output muting

During the early design stages it was assumed that the time taken between applying an input signal and the appearance of the synchronised output signal (hereafter called the lock-up time) would not exceed about 40 ms (i.e. the duration of two television fields). It was thought that up to a field would elapse for the Main Store logic to operate followed by a possible further field for the signal to pass through the Main Store delay.

In practice however the lock-up time was found to be determined mainly by video processing (clamps, blanking amplifiers, etc.), and could be as long as 0·3s (about 15 television fields) for monochrome signals and even longer for colour signals. Moreover, during the lock-up period the output sync pulse train was disturbed by displaced video signals going well below black level with consequent unacceptable effects along the broadcast chain. These disadvantages were emphasised when, during early service trials, the desirability of being able to make 'in-shot' cuts between non-synchronous sources at the synchroniser input became apparent.

Accordingly measures were taken both to minimise the lock-up time and to arrange that automatic 'muting' of the synchroniser output preserved the standard output waveform of uninterrupted synchronising pulses.

The muting system involves several sensing units. Certain sensors detect either the absence of an input signal or non-sync cuts at the input likely to disturb the output waveform. Other sensors detect whether or not Timing Corrector 2 is within range and whether or not the V-axis polarity of the output signal is correct. The outputs of all the sensing units are combined to provide the muting control signal which is arranged so that the synchroniser output is restored during the first field-blanking interval after correct lock-up has occurred. At first the system was designed to mute to black level, but tests showed that it was advantageous to mute instead to a level obtained by integrating the input video signal over several fields. By this means the subjective impression of the muting time resulting from a non-sync cut was approximately halved. The system thus gives the impression of a very fast cross-fade when the input is cut between non-synchronous sources having scenes of high and low mean brightness.

The synchroniser lock-up time was reduced in two ways. First, by arranging that, when loss of an input signal occurred, local station syncs replace those normally derived from the input signal. Second, the input signal burst-locked oscillator (required for deriving the special intermediate-signal colour burst) is maintained in a locked condition by a feed of local station colour bars during either the absence of an input signal to the synchroniser or if the input is a monochrome signal. These measures maintain the synchroniser in a near-normal-colour-operating condition in the absence of an input signal such that the lock-up time is minimised to a range of about 0 to 7 field-periods, for signals within a frequency tolerance of ± 2 parts in 10^4.

4.4 SECAM operation

When a SECAM signal is synchronised it is also inevitably transcoded to PAL. In principle, the transcoding can take place either before or after the synchroniser, but in practice, SECAM signals are synchronised before transcoding. This is because the acceptable frequency tolerance of the input signal is then adequate for the specified SECAM tolerance (± 1 part in 10^4). If a SECAM signal were transcoded first, the acceptable frequency range would be primarily limited to the subcarrier-regeneration system of the SECAM/PAL transcoder, which is only about ± 0·16 parts in 10^4.

5. Summary of synchroniser performance

5.1 Lock-up time (or recovery time following non-sync change): 0 to 7 field periods for input signals within a frequency tolerance of ± 2 parts in 10^4. For signals outside this range, the lock-up time may be increased by up to about 12 field periods in the most unfavourable conditions.

5.2 Input signal frequency tolerances:

PAL input signal to PAL output signal:
± 40 Hz at subcarrier frequency

SECAM input signal to PAL output signal:
± 5·5 parts in 10^4

Monochrome input signal to monochrome output signal:
± 5·5 parts in 10^4

5.3 Distortion:

2T pulse-to-bar ratio	87%
Bar 'K' Rating	2%
2T pulse 'K' rating	4%
Chrom./lum. crosstalk	0%
Chrom./lum. delay inequality	–5 ns
Chrom./lum. gain inequality	0%
Line-time non-linearity	4%
Differential gain distortion	–4%
Differential phase distortion	10°
Lum. sig./noise ratio	46 dB, unweighted. measured with 50% lift

6. Conclusions

The advantages of having picture sources which are synchronous are discussed and the adaptation of the BBC CO6/508 field-store standards converter to the alternative function of a source synchroniser has been described. This involved mainly the development of a control logic system for the Main Store and an additional stage in the timing corrector section; an output signal muting system was also required.

This type of synchroniser can therefore be a relatively inexpensive development of a field-store converter; the cost of the equipment to operate solely as a synchroniser would probably be about one-half that of a field-store converter. It is therefore open to question whether the advantages of this type of synchroniser over alternative methods justify the cost.

Recent considerations indicate that a television field-store synchroniser using digital techniques is now feasible. This would have several advantages including reduced impairment of signal quality, greater input-signal frequency tolerance, greater reliability and probably reduced costs, compared to the analogue equipment described in this report. This therefore appears to be the next logical step in this field of television engineering.

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